

  GLAST LAT TECHNICAL REPORT	Document # <b>LAT-TD-00797-D1</b>	Date Effective 05/31/02
	Prepared by Hartmut Sadrozinski	Supersedes None
	Subsystem/Office Anticoincidence Detector Subsystem	
Document Title <b>LAT Anticoincidence Detector Subsystem Photomultiplier Tube Review</b>		

**Gamma-ray Large Area Space Telescope (GLAST)**

**Large Area Telescope (LAT)**

**Anticoincidence Detector (ACD) Subsystem Photomultiplier Tube  
Review**

# REPORT from the Review of GLAST/LAT ACD PMT Specifications

Version 1.0, May 31, 2002

## SUMMARY

A committee to review the GLAST LAT photo multiplier tube (PMT) procurement met Friday, May 24, 2002, starting at 8:00AM PDT till 12:00 NOON PDT. The IPM's charge is shown in Appendix A, the committee membership in Appendix B, and the details of the meeting in Appendix C.

The committee was impressed by the amount of information presented by the ACD team lead by David Thompson and the willingness of the team to discuss the details of the designs, data and their plans. The review material and additional information was made available on a web site: <http://lhea-glast.gsfc.nasa.gov/acd/pmts/>

Following are recommendations, issues and concerns, followed by the findings. An annotated version of the specs is attached as Appendix D (use "Track Changes" option).

An advance copy of the preliminary list of issues was sent to the ACD manager David Thompson to be used in a discussion with HPK personnel on May 28, 2002. Nick Virmani's notes from the result of this meeting are included as Appendix E, indicating the willingness of the ACD team to make use of our findings.

David Mengers made a strong case for a comprehensive test plan, and Hiro Tajima commented on the acceptance testing. Their comments are attached as Appendix F, since the committee did not have time to discuss them.

## RECOMMENDATIONS, ISSUES + CONCERNS

**Schedule:** The slow procurement rate of 30 tubes/month is determined by the testing time. The actual production time of the 240 tubes will be about 6 weeks. This means that the schedule pressure could be relieved if the testing time at HPK can be shortened. If the long-term burn-in is the pacing item, the need for it and the details of it should be reviewed.

**Contract terms:** The contract specifies the flight PMT to be option 2 of the base contract. The delivery is specified as 10 months after exercising option 2. In the discussion, an additional time constraints of 45days after delivery of the 10 Qual tubes was mentioned, which puts the need to exercise option 2 into the July 2002 time frame. This deadline could not be found in the submitted contract and should be verified. The ACD construction schedule still requires start of procurement before CDR, but not necessarily within the next two months.

**Testing of 10 Qual units:** The decision to procure flight units should only come after the 10 qualification units are tested thoroughly, the performance compared to the specs and the QA questions resolved. Items to be tested are

- Burn-in procedure (including burn-in to fail?), including accelerated testing

- Extrapolation of performance from testing temperature (25°C) to operating temperature (~0°C)

- Temperature cycling

- Correlation between HPK testing and LAT testing results

- Development of acceptance testing procedures

- Built complete flight-like PMT assembly including the selected glues and shake, temperature and vacuum cycle.

**Qualification:** It was pointed out that the 10 Qual units delivered to GLAST LAT will not have been fabricated on the same controlled line as the flight units. This raises the issue of potentially having to test the first flight articles to qualify and/or validate them, and also the need for a thorough test plan. One should assume that there needs to be a scheduled delay between acceptance of the first lot of 30 flight PMTs and the delivery of the next batches, to allow for thorough qualification.

**Burn-in:** Burn-in is both a schedule risk (if done for too long and too low a current) and a performance risk (if done at a current close to the maximum current which stresses the parts). Thus the burn-in specs should be reevaluated. Prediction of end-of-mission performance might be less critical than the weeding out of abnormal performance, which will be apparent after much shorter time scales.

**Q/A Provisions:** Detailed Q/A provisions (shipping, handling, storage, environment, etc included) are missing and have to be drawn up, reviewed and signed off. For the technical part, acceptance tests should be drawn up that allow relating the results both to the manufacturers specification and to the LAT Level 3 performance specification of detecting charged particles in the ACD. Add drawings and HPK proposal to specs.

**Operating Temperature vs. Testing Temperature:** It is important to understand performance and survival issues related to the fact that the testing of the tubes is done at 25°C, while they will be operated between -10°C and +6°C. Some of the issues might be resolved by the test of the Qual units, others might need manufacturers data.

**System Aspects:** The ACD efficiency is a product of light generated in tiles, light collection and transmission efficiency in fibers, cathode efficiency and PMT gain. Some of the efficiencies are not determined yet. For example, if the fiber transmission is below 60%, instead of the assumed 85%, one of the two ACD signals from one tile will not give the required efficiency and both are needed, which will impact the redundancy of the system. The ACD is thinking of proposing to double the number of power supplies to deal with this reduced redundancy. The mass, power, cost impact of this solution should be traded against increasing the thickness of the scintillator tile from 1cm to say 1.25 or 1.5cm.

**Size:** There was concern that the ACD PMTs constitute the outer extent of the LAT and that they could be reduced in lateral size to generate more margin. It turns out that the limiting dimensions are the size of the resistor chain housing, which could be reduced in size somewhat if absolutely required. Also the tubes are in a double row, and staggering them somewhat might give more room, if needed.

## FINDINGS

### General

- 1) Phototubes (PMT) are the right technology for the ACD readout. The committee also agreed with the general procurement philosophy to buy high quality PMT, which have been thoroughly qualified by the vendor. The PMT selected (HPK 4443) is a ruggedized version of a commercial tube R 647 and appears to be the right choice.
- 2) The contract with HPK is for 10 qualification tubes (delivered mid-May 2002) with two options: 40 EM PMT (option 1) and 210 Flight PMT (option 2). The ACD team proposes to exercise only option 2 with an increase in the numbers from 210 to 240. The delivery is specified as 10 month after exercising option 2. In the discussion, an additional time constraints was mentioned of having to exercise the option within 45days after delivery of the 10 Qual tubes. This would put the need to exercise option 2 into the July time frame. This deadline could not be found in the submitted contract and should be verified.
- 3) The ACD construction schedule requires procurement before CDR, but not necessarily within the next two months. The production of the 240 PMT will take about 45 days, with the testing stretching the schedule out such that delivery will be 30 PMT/month. It seems prudent to allow time for thorough testing after the first batch of 30 before accepting the entire batch.
- 4) The specifications submitted refer to the original vendor proposal. This proposal (and applicable drawings) should be made part of the specs.
- 5) The committee noted with surprise that no Q/A provisions were made available by the GSFC team (no traceability plan, and no detailed qualification plan with respect to handling, temperature, long-term testing, soldering of leads etc).
- 6) The vendor is not required to give the ACD team yield data on the manufacturing process. It is recommended that the vendor is allowed to ship PMT only if the batch yield is >70%.
- 7) Shelf life and special provision for handling and storage were discussed. It seems clear that the He contamination has to be avoided by special bagging. Although both O<sub>2</sub> and N<sub>2</sub> were declared no problem, this should be looked at for the maximum temperature of 45°C.
- 8) Test data should be send electronically before and in written form with the shipment.

### PMT details

- 9) There was discussion if a smaller diameter tube should be selected, in order to gain margins in the lateral dimension of the LAT, but it seems that if needed, the tube location on the grid could be modified to give more margin.
- 10) The cathode area has a 10mm diameter, of which 8.5mm is covered by fibers, which avoids having to rely on the outside rim of the cathode that tends to have reduced quantum efficiency.

- 11) The maximum voltage on the tubes is 1250 V, the powers supplies are specified to 1500V. The operating voltage is ~800V (we believe). The maximum current is 100uA at a maximum gain of  $2 \times 10^6$ , the initial dark current  $< 10\text{nA}$ , and the operating gain is  $5 \times 10^5$ .
- 12) It was noted that the ACD team plans to ramp the PMT voltages down to 400V when crossing into the SAA. The effect of these frequent ramps on the performance and specs should be well documented.

#### ACD System issues

- 13) The overall charged particle tracking efficiency depends on the performance of many elements, (scintillator tiles, wave shifting fibers, connectors, clear fibers, PMT, readout ASICs, TEMs), of which the PMT is only a part. It appeared that the performance numbers of only a fraction of these elements are known with sufficient accuracy; only by making assumptions about the unknown values can one assess the overall performance of the ACD system. It is not clear how reliable the simulations are which are used, and continuing testing should be of high priority.
- 14) To increase the confidence that the Level 3 requirements can be satisfied, the ACD is contemplating doubling the number of power supplies. This should be traded against increasing the thickness of the scintillator tiles.
- 15) The Qual tubes should be used to investigate all system issues. For example, several PMT should be assembled into flight assemblies and temperature cycled and random vibrated to ferret out any showstoppers in the assembly.

#### Temperature issues

- 16) The operating temperature of the tubes will be between  $-10^\circ\text{C}$  and  $+6^\circ\text{C}$ . All testing is specified to be done at  $+25^\circ\text{C}$ . (The documents should be scrutinized to ensure they consistently use  $+25^\circ\text{C}$ ). The ACD team should convince themselves that this introduces no bias or performance risk. The 10 Qualification PMT in hand should serve to ascertain the amount of performance extrapolation required between the two temperatures.
- 17) It was noted that maximum temperatures are a hot topic in GLAST system engineering. The ACD should get a blessing on the limiting temperatures and their proposed rate of temperature change on the ground and in flight.
- 18) The temperature specs seem to be OK. Apparently the vendor recommends a maximum upper temperature of  $+50^\circ\text{C}$ , and the ACD is adapting a maximum temperature of  $+45^\circ\text{C}$ . It was not entirely clear if the survival temperature (non-operating) is the same. No temperature cycling has been performed and should be done at least with the Qual units.

#### Testing

- 19) No radiation damage data were presented. The ACD team should present the data.

20) The vendor is required to do random vibrations. The contract refers to a general GEVS test site. The ACD team should ascertain that they are performed to the levels required for the LAT, and spell the levels out in the contract.

21) The testing in the specs should be identified as testing procedures and should make reference to the HPK proposal, regardless if at variance with it.

The ACD team specifies an accelerated burn-in test at 1/3 of the maximum current for 100 hrs. This will not allow one to assess the lifetime of the PMT, but will help to weed out tubes with pathological aging patterns. The committee recommends that the burn-in time is shortened (with increased current?) to gain more schedule margin and reduce the stress on the tubes. (From the data submitted, it appears that 50% of the aging observed after 100 hours is observed already after 24 hours).

22) The aging of the PMT and the gain reduction should be investigated beyond the 50k hours. Qual tubes should be used to learn more about the lifetime of the tubes. The ACD team has a margin of factor 4 in tube gain to offset the aging.

23) The test plan at GSFC is just being developed. An ideal test would allow one to check the vendor data and at the same time assure that the LAT Level 3 requirements can be met at the flight operating temperature. A test using muons takes an entire day, which is too long. Potentially a source or accelerator measurement should be used.

## **APPENDIX A: Instructions from IPM W. Althouse**

### **PURPOSE of ACD PMT REVIEW**

The GLAST/LAT Project will be ready for Critical Design Review (CDR) in April 2003. The ACD subsystem will be ready for CDR at an earlier date, in summer/fall 2002, but needs to initiate a long-lead procurement of PMTs, valued at about \$350K, in June 2002. The purpose of this review is to minimize the risks associated with committing to this purchase before the ACD is fully ready for CDR, i.e., all designs and documentation are "frozen."

### **REVIEW CHARGE**

The review committee should answer the following questions:

1. Has the ACD subsystem team addressed all the issues involving the PMT purchase, for example: are all relevant PMT parameters identified and appropriately specified; are mechanical and electrical interfaces to the PMT well-defined, documented and released to configuration management; are the electronics designed to handle specified variations in PMT characteristics?
2. Is the PMT specification complete (including both technical performance and quality assurance provisions)? Are the specified values appropriate and realistic?
3. Are there any other issues or questions related to this procurement which should be addressed by ACD subsystem management or LAT Project management?

### **REVIEW REPORT**

The committee is asked to produce a written memo report including list of recommended action items to me by Friday, May 31, 2002.

The PMT specifications and background materials have been furnished by the ACD Subsystem Manager, Dave Thompson, through a website pointer  
<http://lhea-glast.gsfc.nasa.gov/acd/pmts/>

## APPENDIX B

### ACD PMT REVIEW COMMITTEE:

H. Sadrozinski, Chair  
L. Barbier  
E. Bloom  
H. Tajima  
N. Virmani

## APPENDIX C

### DETAILS OF REVIEW MEETING 5/24:

#### ATTENDANCE

At SLAC Bldg 28

H. Sadrozinski  
E. Bloom  
H. Tajima  
Dick Horn  
Thomas Borden (part time)  
Ed Washwell (part time)  
Tim Thurston (part time)  
Jim Martin (part time)  
Bill Althouse (part time)

#### By Phone

Louis Barbier  
Nick Virmani  
Robert Hartman  
Alex Moisey  
Thomas Perry  
Tavi Alvarez  
Tony Devinci  
Dave Mengers

#### REVIEW AGENDA

1. Technical presentations and discussion (~1.5 hour)
2. Line-by-line review of the technical specification and QA requirements (~1.5 hour)
3. Discussion of issues, action items, agreement on the action item list (~1 hour)

**APPENDIX D**

	Document #	Date Effective 5-24-02
	Prepared by(s) HFWS	Supersedes None
	Subsystem/Office Anticoincidence Detector Subsystem	
Document Title <b>Annotated Specifications for ACD Photomultiplier Tubes</b>		

**Annotated Specifications for ACD Photomultiplier Tubes**

**-Attach HPK proposal-**

**ORDER FOR SUPPLIES OR SERVICES**

PAGE 1 OF 1

IMPORTANT: Mark all packages and papers with contract and/or order numbers.

1. DATE OF ORDER

**NOV. 30, 2001**

2. CONTRACT NO. (If any)

6. SHIP TO:

3. ORDER NO.

S 60463 G

4. REQUISITION/REFERENCE NO.

**740-09742A(1P)**

a. NAME OF CONSIGNEE

NASA/GODDARD SPACE FLIGHT CENTER

b. STREET ADDRESS

GREENBELT ROAD

c. CITY

GREENBELT

f. SHIP VIA

d. STATE

MD

e. ZIP CODE

2

5. ISSUING OFFICE (Address correspondence to)

NASA's Goddard Space Flight Center  
ATTN: MS. VERONICA C. STUBBS  
GREENBELT, MD 20771

7. TO:

a. NAME OF CONTRACTOR

HAMAMATSU CORPORATION

b. COMPANY NAME

HAMAMATSU CORPORATION

c. STREET ADDRESS

360 FOOTHILL ROAD

d. CITY

BRIDGEWATER

e. STATE

NJ

f. ZIP CODE

08807

9. ACCOUNTING AND APPROPRIATION DATA

**JON: 743-785-20-31-02; APP: 801/20110(01); BLI:  
A701**

**OC: 74-2550; AMT:\$16,000.00; BN/C: 202**

11. BUSINESS CLASSIFICATION (Check appropriate box(es))

☐ a. SMALL☒ b. OTHER THAN SMALL☒ a. PURCHASE

REFERENCE YOUR: \_\_\_\_\_

Please furnish the following on the terms  
and conditions specified on both sides of  
this order and on the attached sheets, if  
any, including delivery as indicated.

8. TYPE OF ORDER

☐ b. DELIVERY - Except for  
instructions on the reverse, this  
is subject to instructions contained  
only of this form and is issued  
terms and conditions of the above  
contract.

g. PPC CODE

**GF**

h. STATE CODE

10. REQUISITIONING OFFICE

12. F.O.B. POINT

NASA/GODDARD SPACE FLIGHT CENTER

14. GOVERNMENT B/L  
NO.15. DELIVER TO F.O.B. POINT  
ON

16. DISCOUNT TERMS

13. PLACE OF

MARCH 1, 2002

a. INSPECTION

b. ACCEPTANCE

17. SCHEDULE (See reverse for Rejections)

ITEM NO. (A)	SUPPLIES OR SERVICES (B)	QUANTITY ORDERED (C)	UNIT (D)	UNIT PRICE (E)	AMOUNT (F)
1	IN ACCORDANCE WITH THE ATTACHED STATEMENT OF WORK, ADDITIONAL TERMS, AND THE CONTRACTOR'S PROPOSAL DATED OCTOBER 8, 2001, THE CONTRACTOR SHALL PROVIDE PHOTOMULTIPLIER TUBES (PMT'S) TO BE USED IN THE GLAST ACD	10	EACH	\$1,600.00	\$16,000.00

SEE ATTACHED FOR ADDITIONAL TERMS

SEE BILLING

18. SHIPPING POINT

19. GROSS SHIPPING

20. INVOICE NO.

\$16,000.00

Hard copies of this document are for REFERENCE ONLY and  
should not be considered the latest revision.

## 21. MAIL INVOICE TO:

a. NAME

NASA GODDARD SPACE FLIGHT CENTER

b. STREET ADDRESS (or P.O. Box)

\$16,000.00

ACCOUNTS PAYABLE CODE 155

c. CITY

GREENBELT

d.

MD

e. ZIP CODE

20771

22. UNITED STATES OF  
AMERICA BY  
(Signature)

DATE

23. NAME (Typed)

JAMES S. KING

TITLE: CONTRACTING OFFICER

**ORDER NUMBER S-60463-G**  
**ADDITIONAL TERMS**

**Accounting and Appropriation Data**

PCN: 740-09742A(1P)  
JON: 743-785-20-31-02  
APP: 801/20110(01)  
BLI: A701  
OC: 74-2550  
AMT: \$16,000.00

TOTAL: \$16,000.00  
BNC: 202

**ADDITIONAL TERMS**

## Delivery Schedule

1. Basic Contract--Ten (10) Qualification Unit PMT's shall be delivered on or before

March 1, 2002.

2. Option 1--Forty (40) Engineering Unit PMT's shall be delivered on or before June 1, 2002.

3. Option 2--Two hundred ten (210) Flight Unit PMT's shall be delivered within ten (10) months after the exercise of this option. Looks like Option 2 can be exercised at any time?

When was the Qual units delivered? If in May, the contract is void anyway. So you have some wiggle room.

Delivery shall be FOB Destination to the Goddard Space Flight Center Greenbelt, MD 20771.

OPTION FOR INCREASED QUANTITY. THE GOVERNMENT MAY INCREASE THE QUANTITY OF SUPPLIES CALLED FOR IN THE SCHEDULE AT THE UNIT PRICE SPECIFIED IN ACCORDANCE WITH FAR CLAUSE 52.217-6, OPTION FOR INCREASED QUANTITY AS FOLLOWS:

<u>PRICE</u>	<u>OPTION</u>	<u>DESCRIPTION</u>	<u>QUANTITY</u>	<u>UNIT</u>
	<u>TOTAL</u>	<u>PRICE</u>		
	1	Engineering Unit PMT	40	
\$1,640.00		\$65,600.00		
		Tested to Level 3		
	2	Flight Models Tested to		
		Level 3	210	\$1,350.00
		\$283,500.00		

Note: We expect to change the quantity from 210 to 240 to allow sufficient spares.

NO CHANGES ARE TO BE MADE TO THIS PURCHASE ORDER WITHOUT THE PROPER AUTHORIZATION FROM GSFC PROCUREMENT.

CONTRACTUAL INQUIRIES SHOULD BE DIRECTED TO VERONICA C. STUBBS, CODE 216, GSFC, GREENBELT, MD 20771, PHONE (301) 286-8386 OR FAX (301) 286-1773, EMAIL [Veronica.C.Stubbs.1@gsfc.nasa.gov](mailto:Veronica.C.Stubbs.1@gsfc.nasa.gov)

PRICE PER WRITTEN QUOTE DATED OCTOBER 8, 2001 BY ANDREW ALLEN OF HAMAMATSU CORPORATION

VENDOR'S TAX IDENTIFICATION NUMBER: 13-2638233.

EQUIPMENT USER: DR. ROBERT HARTMAN, CODE 661, PHONE, (301) 286-7178.

THE CONTRACTOR'S INVOICE SHALL CITE ITS TAX IDENTIFICATION NUMBER.

**STATEMENT OF WORK/SPECIFICATIONS**  
**GLAST ACD PHOTOMULTIPLIER TUBES**

The Gamma-ray Large Area Space Telescope (GLAST) Anticoincidence Detector (ACD) requires 230 small photomultiplier tubes. Photomultiplier tubes are the sensor of choice for the low light levels coming from the plastic scintillators. The high efficiency required for anticoincidence demands a photomultiplier tube with capability of detecting single photoelectrons. All tubes must be sufficiently reliable and tested for space flight use.

This procurement is for Photomultiplier Tubes that meet the Photomultiplier Tube (PMT) Requirements detailed below, to be delivered according to the schedule detailed elsewhere in this contract.

All test data shall be delivered with each PMT, either electronically and by paper copy. Specify here which data? All of Testing section below? How about traceability

Failure reports shall be submitted on any PMT's that fail to meet the Performance Requirements after testing (see below).

**PHOTOMULTIPLIER TUBE REQUIREMENTS**

**PHYSICAL REQUIREMENTS FOR THE PHOTOMULTIPLIER TUBES**

1. Head-on type cylindrical tube
2. Bi-alkali cathode
3. Outside diameter less than or equal to 15.2 mm
4. Length less than or equal to 80 mm, not including leads
5. Flying lead connections at least 33 mm long, with ends tin-lead solderable to within 10 mm from the glass stem Need Q/A provisions on soldering
6. Minimum cathode diameter 9 mm
7. As delivered, all PMT's shall be soldered to a temporary base to enable initial electrical testing.

**PERFORMANCE REQUIREMENTS FOR THE PHOTOMULTIPLIER TUBES**

1. Minimum current gain at maximum high voltage shall be 2,000,000 (2E+6).

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should not be considered the latest revision.**

2. Quantum efficiency shall be greater than 15.5% (15% for the qualification tubes) at a wavelength of 490 nm.
3. Anode dark current shall be less than 10 nanoamps at a gain of  $5E+5$  and a temperature of 20 C.

Is voltage at which the gain is  $5E+5$  part of the specs?

4. High voltage required at a gain of  $2E+6$  shall not exceed 1250 V.

5. Projected gain degradation shall be less than 30% (84% probability) after 50,000 hours of operation at a mean anode current of 30 nanoamps. The projection shall be based on accelerated life tests at higher currents with tubes of the same design. Proposals shall detail how such tests have been conducted. Except as required below, the PMT's to be delivered under this solicitation shall not undergo such extended accelerated life tests. *Need model for accelerated testing*

#### ENVIRONMENTAL REQUIREMENTS TO BE MET BY THE PHOTOMULTIPLIER TUBES

1. Temperature range: The PMT's shall operate within specification over a range -30 C to +45 C. *Are these numbers agreed upon by SE? Do we have specs for -30°C? Are we not saying that they should survive the temps and afterwards work within specs in the specified range?*
2. Temperature rate (dT/dt): the PMT's shall operate within specification while experiencing temperature change (within the above range) at a rate of (flight) 5 C/hr; and (test) 20 C/hr. *Are these numbers agreed upon by LAT SE?*
3. Temporal stability: At a constant temperature of 20 C, gain variation shall be less than 2% per 10 days. *With or without HV ramping down to 400V.*
4. Vibration: The PMT's shall operate within specification, and with parameter changes not exceeding the values shown below, after experiencing a Delta2 Qualification Level vibration environment in accordance with <http://arioch.gsfc.nasa.gov/302/gevs-se/sec2-4.pdf>. *Check that HPK used the latest GLAST LAT requirements*
5. Shock: The PMT's shall operate within specification, and with parameter changes not exceeding the values shown below, after experiencing Delta2 Qualification Level shock testing in

accordance with <http://arioch.gsfc.nasa.gov/302/gevs-se/sec2-4.pdf>. Check that HPK used the latest GLAST LAT requirements

6. Radiation: the units shall operate within specification, and with parameter changes not exceeding the values shown below, after a total dose of 10 kRad. Show radiation damage numbers

Limits on Performance Changes Due to Vibration, Shock, or Radiation

Quantum efficiency shall not change by more than 10%;

Current gain shall not change by more than 25%;

Anode dark current (at a temperature of 20 C) shall not increase by more than 100% if it is initially greater than or equal to 1 nA. If the initial anode dark current is less than 1 nA, it shall not increase by more than a factor of 10 after vibration, shock, or radiation.

(All three of the parameters listed above must be within specification both before and after the vibration, shock, or radiation exposure.)

#### **QUALITY REQUIREMENTS TO BE MET BY THE PHOTOMULTIPLIER TUBES**

1. The Photomultiplier Tube Quality Plan shall be consistent with the following:

ISO-9001;

GSFC 433-MAR-0001, "The Mission Assurance Requirements for the Large Area Telescope;"

LAT Performance Assurance Implementation Plan (SLAC LAT-MD-00039);

"Quality Plan for the Anticoincidence Detector" (GSFC ACD-QA-8001).

2. The PMT's must be space flight qualifiable according to 433-SPEC-0001 (GLAST, Mission System Specification).

#### **TEST Procedure- QUALIFICATION UNIT PMT'S (LEVEL 2 TESTING):**

1) Visual Inspection (as per HPK proposal)

2) DC Measurements (quantum efficiency at 490 nm, anode luminous sensitivity at 1250V, derived current gain at 1250V, nominal voltage for gain of 5E+5, anode dark current at gain of 5E+5). Any PMT that fails to meet the performance requirements listed above shall be rejected. Failure reports are not required on PMT's rejected at this point.

3) Random vibration - The ten (10) Qualification Unit PMT's shall be vibration tested by the contractor to the Delta2 Qualification Level specified in <http://arioch.gsfc.nasa.gov/302/gevs-se/sec2-4.pdf>. Again check that the correct GLAST LAT numbers were used. The PMT's shall meet the above performance requirements both before and after the vibration test. Furthermore, changes in performance parameters following the vibration test shall not exceed the limits shown above under "Limits on Performance Changes Due to Vibration, Shock, or Radiation."

4) Visual Inspection (window or envelope defects, loose particles, internal structure) is this different than the inspection in the HPK proposal?

5) DC Measurements as in 2) - Any PMT that fails to meet the performance requirements listed above shall be rejected. Failure reports are required on PMT's rejected at this point.

6) 12-hour Burn-in what current? LAT should do the proposed burn-in on Qual units

7) Visual Inspection (repeat item #1)

8) DC Measurements as in 2) - Any PMT that fails to meet the performance requirements listed above shall be rejected. Failure reports are required on PMT's rejected at this point.

All test data (from steps 2, 5, and 8 above) shall be delivered before or at the same time a PMT is delivered.

The Qualification Unit PMT's shall not be subjected to the 100-hour burn-in described below.

**TESTING PROCEDURE- ENGINEERING AND FLIGHT UNIT PMT'S (LEVEL 3 TESTING) :**

1) Visual Inspection (window or envelope defects, loose particles, internal structure)

Different from HPK proposal?

2) DC Measurements - (quantum efficiency at 490 nm, anode luminous sensitivity at 1250V, derived current gain at 1250V, nominal voltage for gain of  $5E+5$ , anode dark current at gain of  $5E+5$ ). Any PMT that fails to meet the performance requirements listed above shall be rejected. Failure reports are not required on PMT's rejected at this point. HPK shall not deliver tubes from a batch with a yield <70%.

3) Random vibration -

Following the testing described above, each PMT shall be vibration tested at Delta2 Flight Acceptance Level in accordance

with <http://arioch.gsfc.nasa.gov/302/gevs-se/sec2-4.pdf> Latest requirements for GLAST?

4) Visual Inspection (repeat item #1)

5) DC Measurements (quantum efficiency at 490 nm, anode luminous sensitivity at 1250V, derived current gain at 1250V, nominal voltage for gain of  $5E+5$ , anode dark current at gain of  $5E+5$ )

Failure reports shall be submitted on any Engineering Unit or Flight Unit PMT's that fail to meet the Performance Requirements, or which demonstrate performance changes in excess of the limits shown above under "Limits on Performance Changes Due to Vibration, Shock, or Radiation" after vibration testing. Such failure shall be reported to the Technical Officer (of HPK? GLAST?) within two (2) working days. The failed PMT shall undergo failure analysis, the results of which shall be delivered at a mutually agreed upon time, based on the type of failure.

6) 100-hour Burn-in - Following the testing described above, each Flight Unit PMT shall be operated at 30 microamp anode current for 100 hours (gain drift characterization), with the Current Amplification measured initially and after 12, 24, 48 and 100 hours of operation. Consider < 20 hours. You certainly don't want to do this at the maximum current, but is 30uA safe?. Why is this done?

7) Visual Inspection (repeat item #1)

8) DC Measurements - The full set of performance parameters (quantum efficiency at 490 nm, anode luminous sensitivity at 1250V, derived current gain, nominal voltage for gain of  $5E+5$ , anode dark current at gain of  $5E+5$ ). Any PMT shall be rejected, and a Failure Report submitted, if its post-burn-in Cathode Luminous Sensitivity, Anode Dark Current (at 20 C temperature), or Current Gain differs from the pre-test value by more the limits shown above under "Limits on Performance Changes Due to Vibration, Shock, or Radiation", or if it no longer meets the Performance Requirements shown above. Furthermore, any PMT whose gain has decreased by more than 10% after the first 12 hours, or by more than 25% after the full 100 hours, shall be rejected; a Failure Report shall be submitted on such a PMT. How about large increases in gain? Like #7 in Fig. 3 LAT-TD-00760?

All test data from steps 2, 5, and 8, as well as the gain data from the gain tests at 0, 12, 24, 48, and 100 hours, shall be delivered before or at the time each Flight Unit PMT is delivered. Why not results of visuals?

Need to specify where the data will be sent. What form.

## APPENDIX E

### **Nick Virmani's notes from the 5/28 meeting between LAT ACD personnel and HPK**

- 1) Data sheet provided for 10 qualification units will be modified to reflect correct QE as 15.0.
- 2) QE will be measured after completion of all environmental tests. PMTs for environmental testing will have SK ( $\mu\text{A/Lm}$ ) of 70 typical, where SK = Cathode sensitivity.
- 3) Yield of selected PMTs after environmental testing will be a minimum of 70%.
- 4) All measurement will be performed at 25°C and not at 20°C as mentioned in the qualification data sheets.
- 5) Hamamatsu will perform thermal cycling on PMTs from -30°C to 45°C with a rate of change not to exceed 10°C/hr on PMTs manufactured with qualification units.
- 6) Hamamatsu will characterize PMTs over operating temperature range of -10°C to +6°C.
- 7) The maximum voltage on the PMTs is 1250V. The system will have sufficient controls in place to control voltage below 1250V.
- 8) Hamamatsu has characterized PMTs to voltage down to 400V and the data will be available for review.
- 9) Radiation data presented in Hamamatsu proposal for Borosilicate glass was reviewed and the data is acceptable.
- 10) Any failures observed during environmental testing will be recorded and failure analysis report will be available for review.
- 11) Gain drift test data will be measured at 0, 12, 24, 48, and 100 hours.
- 12) A detailed test plan will be prepared which will include receiving inspection of tubes, minimum testing to verify the data integrity and shipping and handling damage, storage, handling precautions required from helium damage. Any helium above normal atmospheric levels is too much and even atmospheric concentration may be too much for the expected several years lifetime before launch.
- 13) QA plan will be developed and will be submitted to Hamamatsu for verification.

- 14) Dave Thompson has agreed to reverify the vibration/shock levels for flight acceptance testing.
- 15) Low level (2 gauss or less) magnetic fields will simply affect PMT operation and not permanently degrade the tube or affect its lifetime. The PMTs will be magnetically shielded in their application in the ACD. However, “strong” magnetic fields can cause self magnetization of the PMT dynodes, which would cause permanent degradation if not subsequently demagnetized. This is only a storage and pre-launch concern since the on-orbit fields are known and the tubes will be shielded. The tubes should be stored away from “strong” magnetic fields. Unfortunately the documentation did not quantify “strong” for the selected Hamamatsu PMTs. Demagnetization would consist of application of an AC magnetic field.
- 16) Flying leads of PMTs will be lead tinned dipped using methods described in NASA 8739.3.

## APPENDIX F:

**David Menger's comments:**

There are several off-line tests that should be conducted to provide a database of performance information for possible future trend analyses. One test would be a life test where several PMTs would be operated continually at a nominal temperature and operational mode. Performance parameters would be recorded periodically. A similar test would be conducted, except now the PMT temperatures would be continuously cycled over the specified operational temperature range. The reason for using multiple PMTs for each test is an attempt to provide some statistical data. The PMTs used in the testing should be randomly selected from the flight units.

One issue raised at the review was the close spacing of the PMTs and the possible difficulties in installing them. Given the tight clearances, I would expect a well specified procedure to be needed. A mock-up of a portion of the PMT/mounting interface rail would be a useful tool for establishing that procedure and for practicing the installation of the PMT's. I am aware that this would likely require the procurement of additional PMTs, but the quantity needed is not that much. The risk reduction would easily justify the added cost.

**Hiro Tajima's comments:**

I would like to comment on the acceptance test since we did not have time to discuss this issue in detail last Friday.

**\* Fit procedure**

It is not clear to me how each quantity is derived. For example, there are numbers of ways to measure peak height. It should be noted that it often leads to mismeasurement if we use raw peak height when asymmetric distribution is smeared. I would suggest to fit the distribution with a Poisson probability density function convolved by a Gaussian function. Free parameter will be  $N_{pe}$ , a conversion factor from 1 P.E to ACD count and Noise sigma. The noise sigma can be obtained independently from the pedestal distribution.

**\* Event selection**

Another issue is the event selection. When we are dealing with low statistics data, we may want to get rid of low momentum muons by cutting on the pulse height of S2 trigger counter.

**\* Trigger counter size**

We may want to consider increasing the size of the trigger counter. 5cmx5cm trigger tile is used for 20cmx20cm reference tile. I understand that smaller trigger tile is preferred to minimize the edge effect. It is not clear to me if 10cmx10cm trigger tile is unacceptable. It will increase the statistics by a factor of 4. (we need to increase the distance between the two trigger tiles to keep the angular acceptance same.)

Anyway, we should start discussion on the issue of acceptance test soon.